

ABSTRACT

Title of Dissertation: RELATIONSHIPS BETWEEN TURBULENT
WALL PRESSURE AND
VELOCITY FIELD SOURCES

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Although the study of wall pressure fluctuations (WPFs) has a long and venerable history, relatively little is known about the nature of the source terms responsible for the wall pressure. This study takes advantage of the three-dimensional velocity fields available from turbulence simulations to try to answer some long-standing questions about the nature of WPFs. Which parts of the boundary layer generate the various wavenumber regions of the wall pressure? What are the dominant source terms? What are the relative magnitudes of the mean-shear (MS) and turbulence-turbulence (TT) wall pressures? What physical processes in the boundary layer generate the wall pressure?

The velocity field sources and partial wall pressures were computed from a database generated by a direct numerical simulation of a low Reynolds number,

fully developed, turbulent channel flow. Results show that the mean-shear (MS) and turbulence-turbulence (TT) partial pressures (π^{MS} and π^{TT} , respectively) are the same order of magnitude. The buffer region dominates most of the wavenumber range; the viscous shear layer is significant at the highest-wavenumbers; buffer and logarithmic regions are important at low-wavenumbers. The dominant length scales of the MS source term indicate that it is generated by near-wall shear layers. Over most of the wavenumber range, the contribution from the buffer region is the dominant TT component; in the low-wavenumber range the viscous shear-layer, buffer region, and logarithmic region are dominant; in the medium- and high-wavenumbers the viscous shear-layer and buffer region. The most important TT partial pressures are π_{23}^{TT} , π_{13}^{TT} and π_{12}^{TT} from the buffer region. It is hypothesized that π_{23}^{TT} and π_{13}^{TT} are generated by quasi-streamwise vortices that are parallel and tilted with respect to the wall, respectively. π_{12}^{TT} may be due to near-wall shear layers and spanwise vortices, but is much less important than π^{MS} . π_{23}^{TT} , π_{22}^{TT} and π_{33}^{TT} from the viscous shear-layer are the dominant high wavenumber partial pressures; they may be due to the downward side of quasi-streamwise vortices impinging on the wall.

Modelling the MS pressure depends upon the vertical velocity field. It was shown that the streamwise spectra of v , normalized by its mean square, is constant across the channel. The peak of the spanwise spectra, however, shifts towards lower wavenumbers with distance from the wall. The $k_z\delta$ location of the peak varies as y^0 , $y^{-1/3}$ and y^{-1} in the viscous shear-layer, buffer layer, and logarithmic region, respectively. Further efforts are necessary to scale the amplitude of the spanwise v spectra. For $y/y' \leq 1.0$, the broadband correlations were shown to collapse to a single curve when plotted versus y/y' .